

AlGaIn/GaN HEMT OPTICAL PUMPING EXPERIMENTS

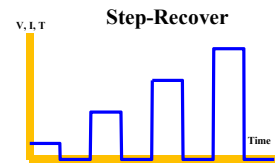
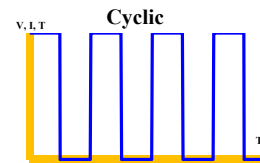
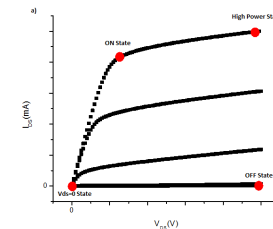
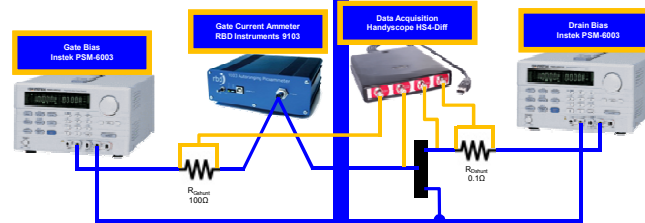
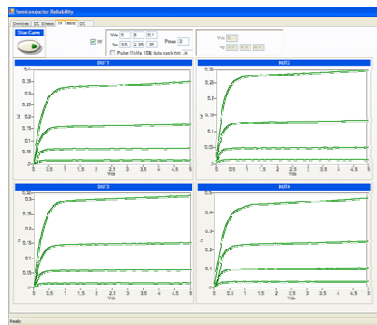
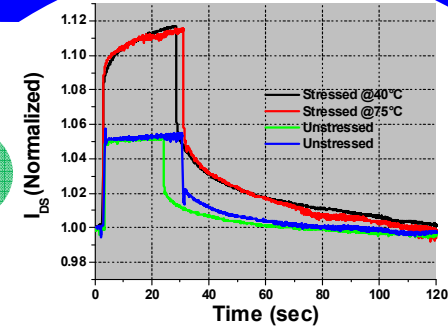
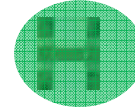
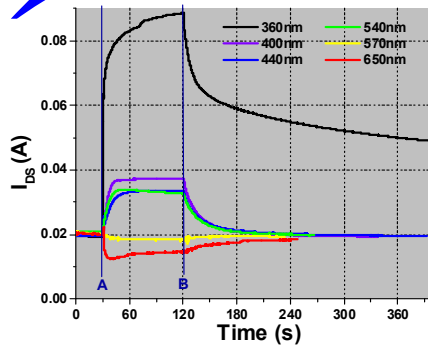
David Cheney, Pat Whiting, Erica Douglas, Jennilee Navales,
Fan Ren, Brent Gila

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Reliability Test Station


FLOORS



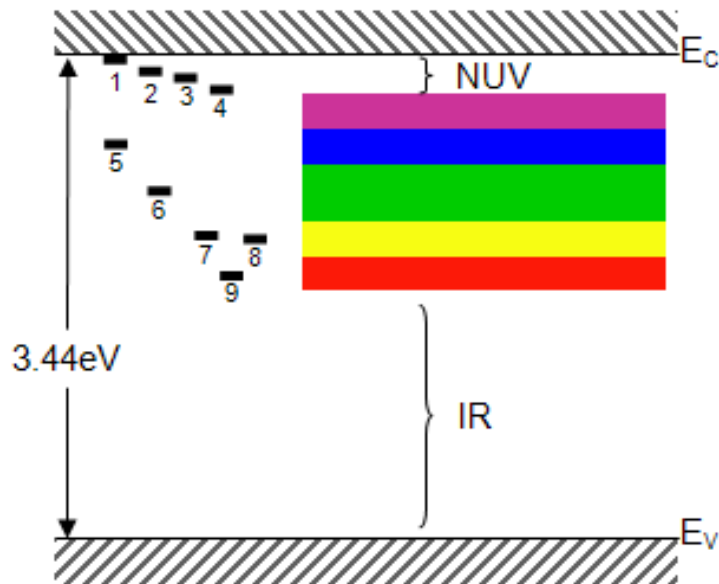
$t=0$, As Built

$t>0$, Degradation

Motivation

- Non-destructive indicator of trap densities
- Device characterization
- Defect  Reliability

BACKGROUND



Defect 1	3.41 eV	basal plane stacking faults on polar GaN [ref 1] basal plane stacking faults on non-polar GaN [ref 2] a-type threading dislocations [ref 3]
Defect 2	3.34 eV	a-plane stacking faults [ref 1]
Defect 3	3.28 eV	partial dislocations [ref 1]
Defect 4	3.20 eV	C_N [ref 4]
Defect 5	2.9 eV	Blue defect - O_N , dopants [ref 5]
Defect 6	2.5 eV	Green defect - $V_{Ga}O_N$, dopants [ref 5]
Defect 7	2.2 eV	Yellow defect - several vacancy defect models, V_{Ga} bound to dislocation, dopants [ref 5]
Defect 8	2.21 eV	edge dislocations (screw dislocations are invisible) [ref 6]
Defect 9	1.8 eV	Red defect - $V_N C_N$, implant damage, dopants [ref 5]

1. R. Lui et al; APL **86**, 021908 (2005)
2. Z.H. Wu et al; APL **92**, 171904 (2008)
3. M Albrecht et al.; APL **92**, 231909 (2008)
4. C. Diaz-Guerra et al.; JAP **100**, 023509 (2006)
5. M.A. Reshchikov and H. Morkoc; JAP **97**, 061301 (2005)
6. N. Yamamoto et al; JAP **94**(7), 4315(2003)
7. A. Istratov, O. Vyvenko; Review of Scientific Instruments, Vol 70, Num 2 (1999)

EXPERIMENTAL SETUP

Laser	E _v
Red 650nm <100mW	1.91 eV
Green 532nm <100mW	2.33 eV
Blue 445nm <1W	2.79 eV
Violet 408nm <100mW	3.04 eV
HeCd 325nm <100mW	3.81 eV

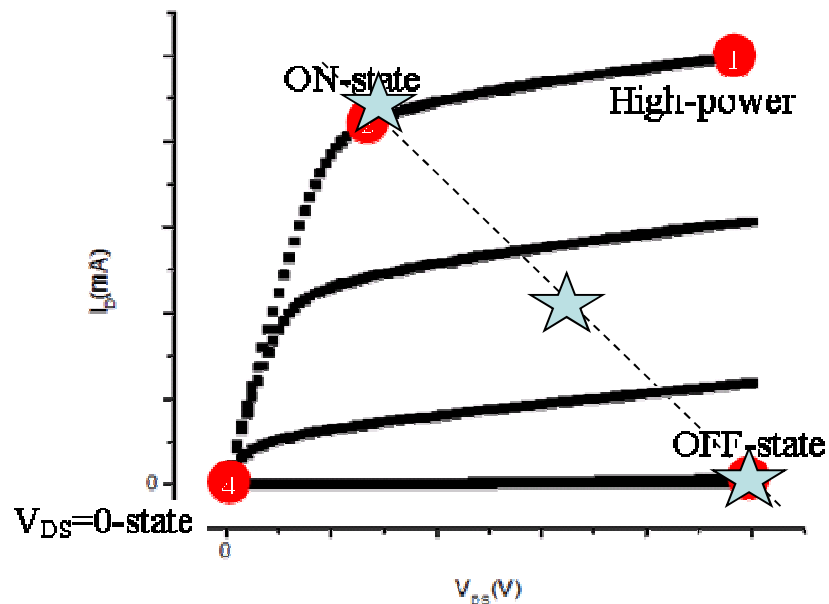
1. Expose DUT with different wavelengths of light and measure changes in drain current
2. Establish baseline for each wavelength
3. DC Stress
4. Compare with baseline

EXPERIMENTAL SETUP

Three devices along a load line of $\sim 1\text{ W}$
AFRL AlGaIn/GaN HEMTs, dual gate 170nm

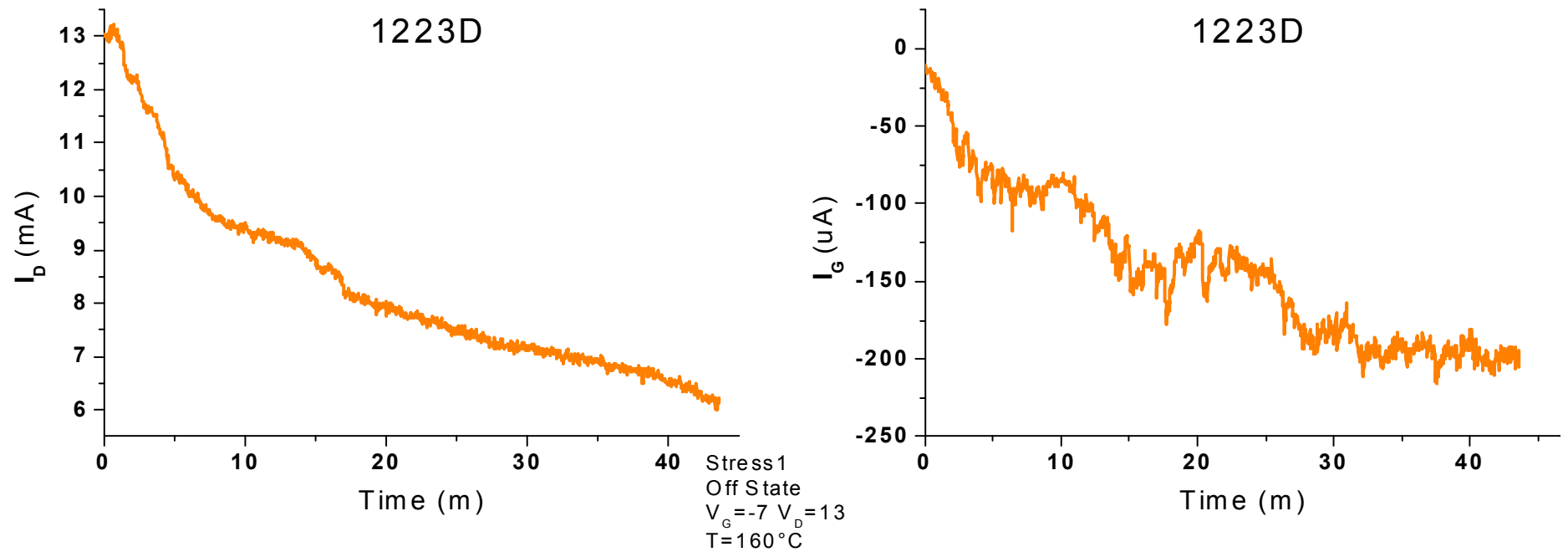
1624D	$V_{DS} = 5, V_{GS} = 0$	On-state
1622D	$V_{DS} = 9.2, V_{GS} = -2$	
1223D	$V_{DS} = 13, V_{GS} = -7$	Off-state

DC stress until I_D decrease by 20% or I_G increase by 10x

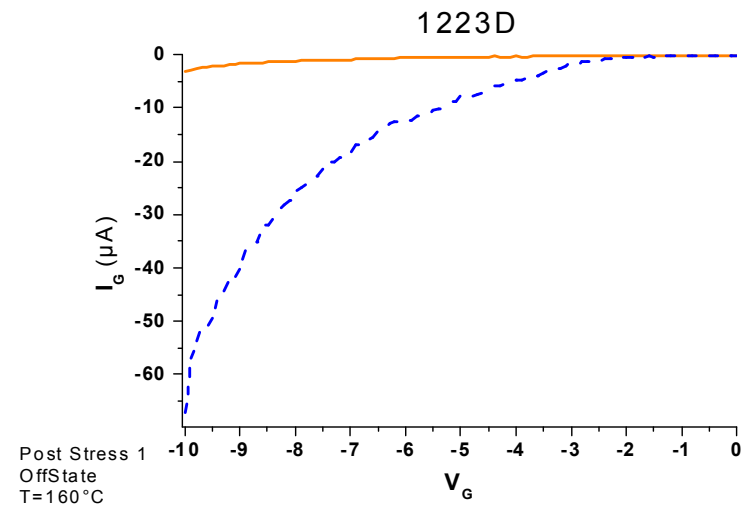
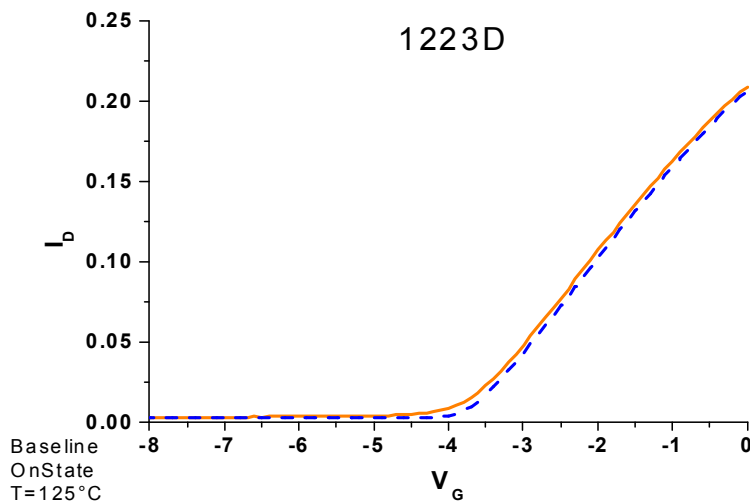
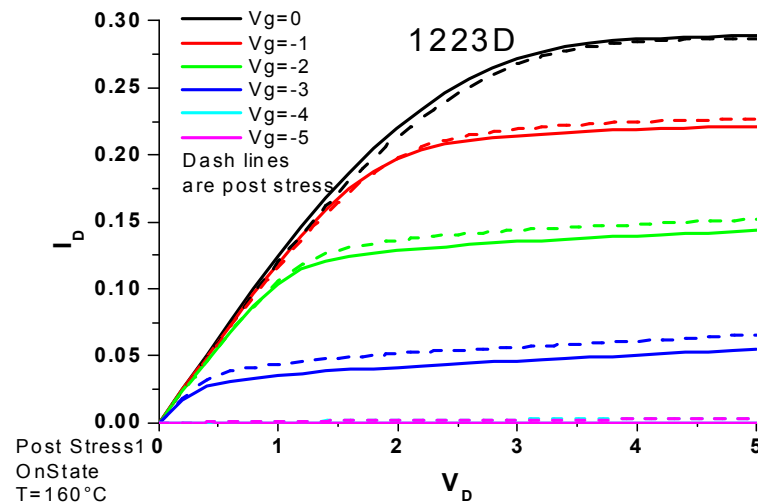


RESULTS

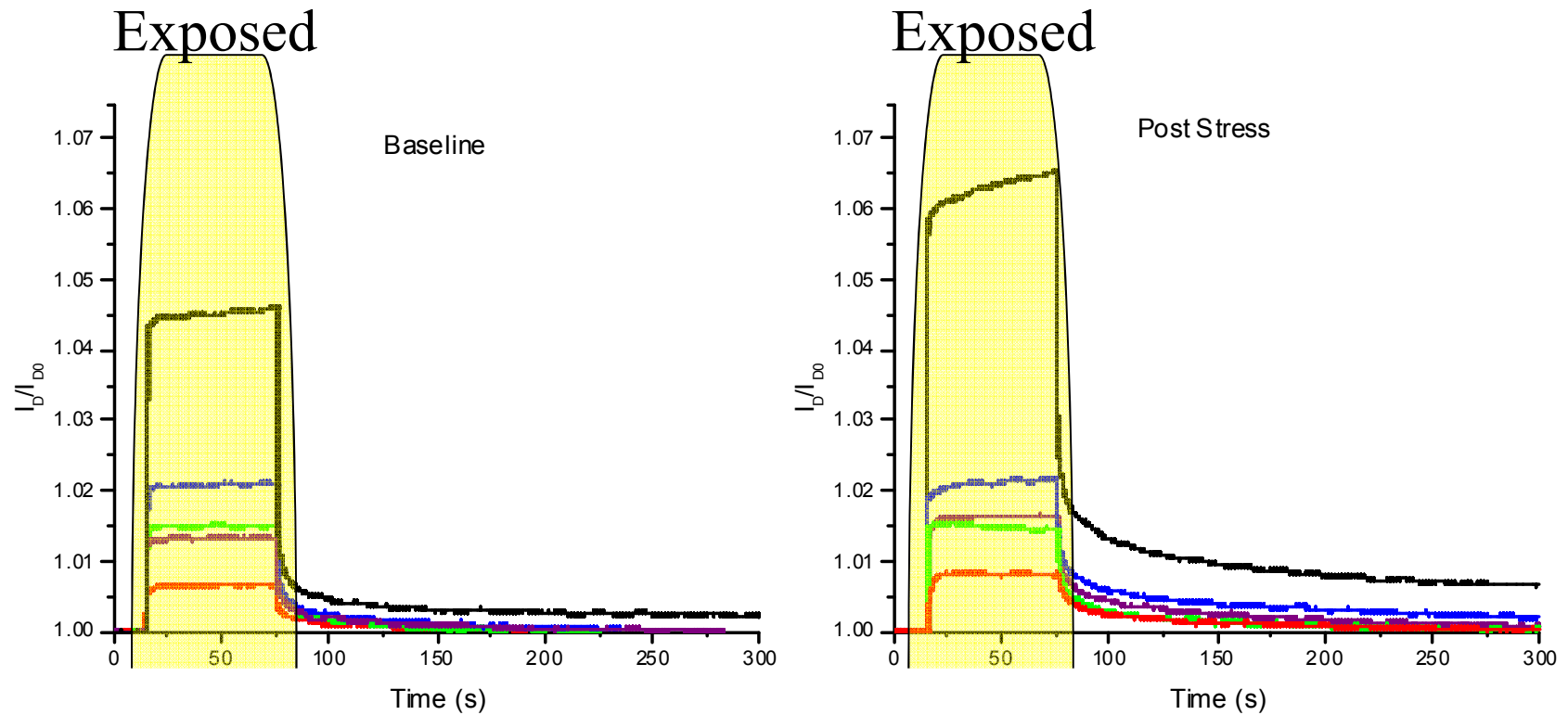
Device 1223D Off-state failed within an hour



RESULTS



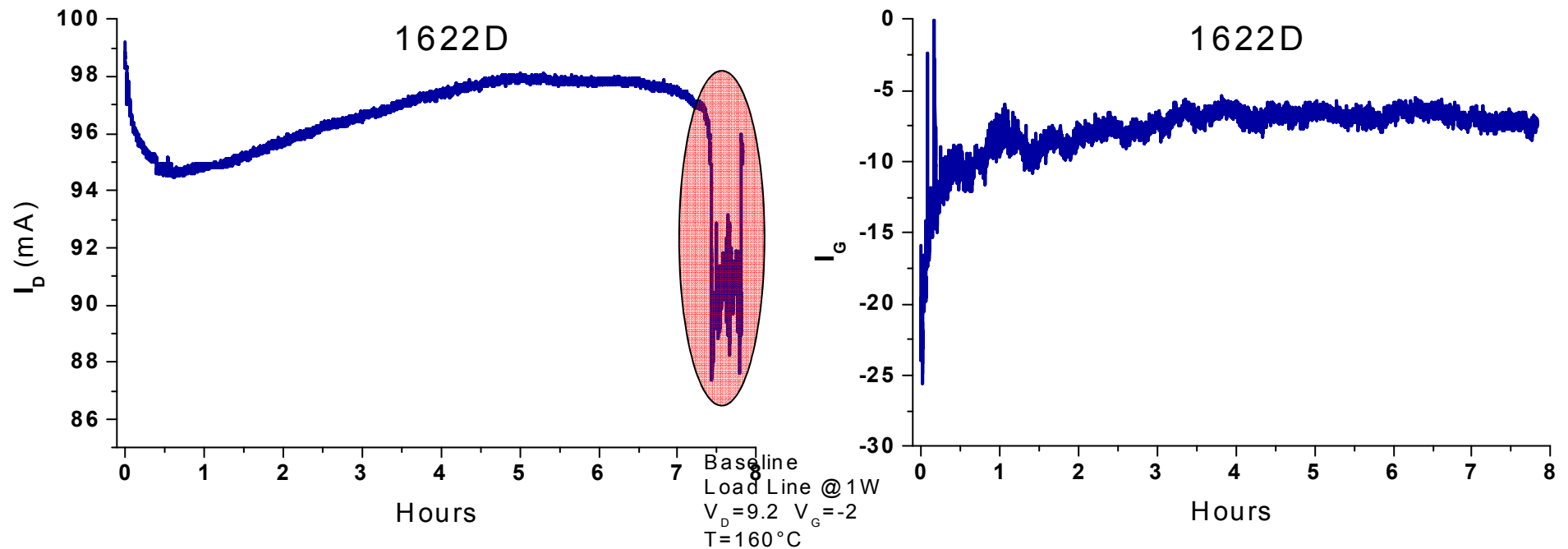
RESULTS



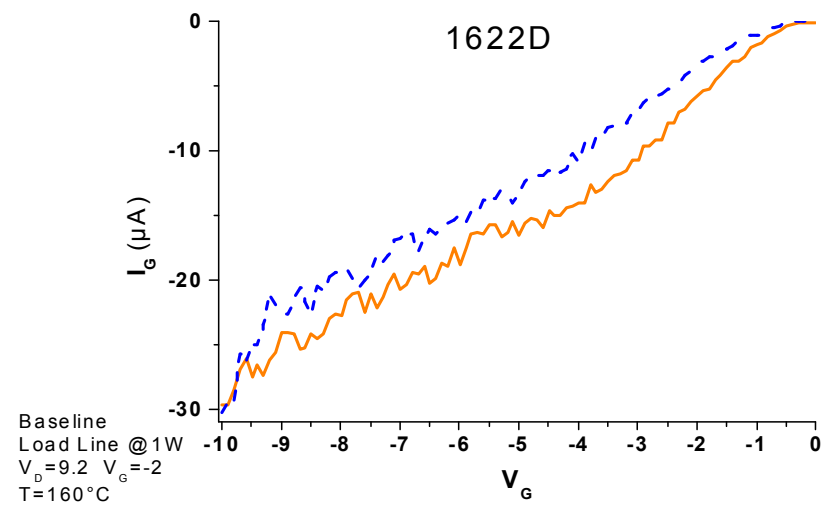
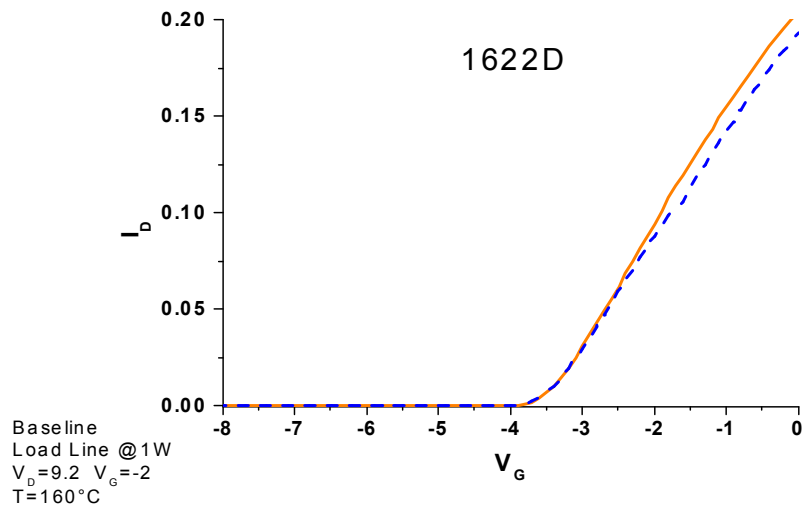
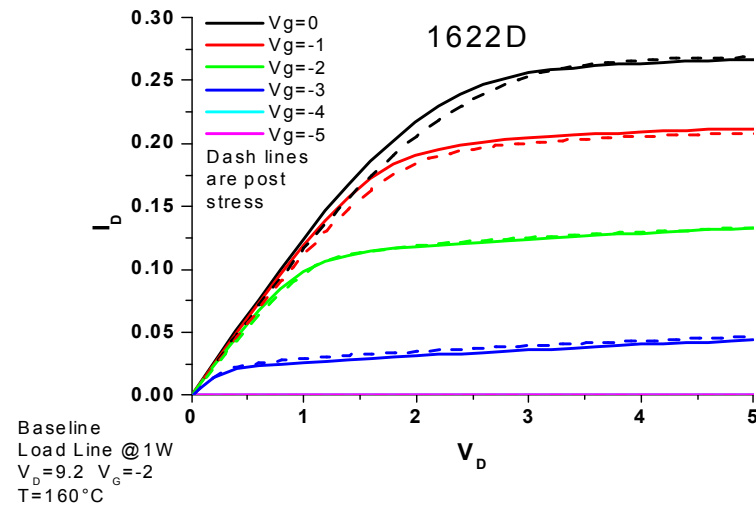
- Increase in red, violet, and UV
- No change in green and blue

RESULTS

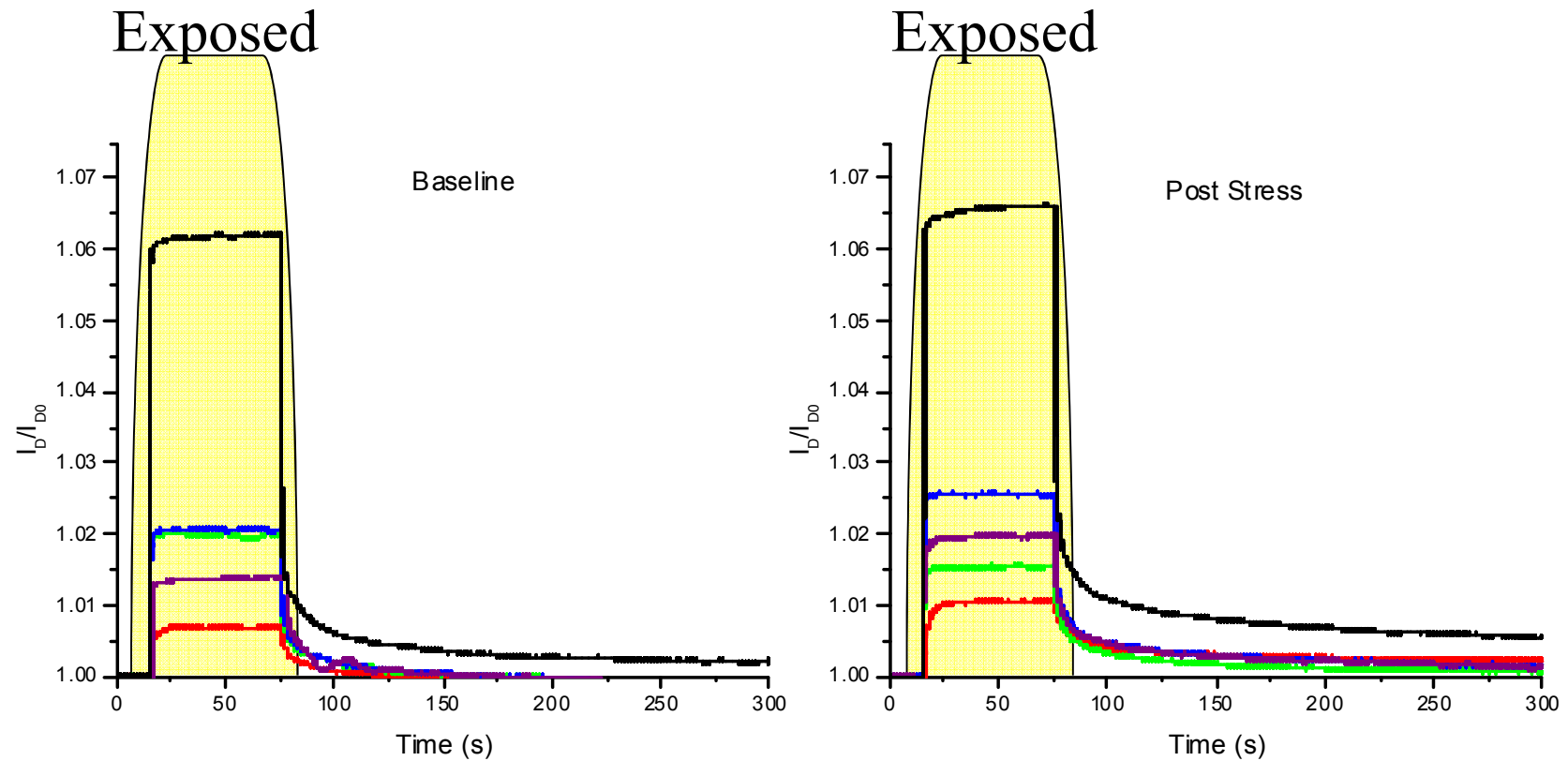
Device 1622D did not reach threshold, but showed degradation



RESULTS



RESULTS



- Increase with all wavelengths
- Green shows a decrease???

SUMMARY

- Off-state stress
 - Were changes in electrical characteristic tests
 - Moderate differences with optical measurements
- Device 1622D
 - Little changes in electrical IV plots
 - Noticeable optical measurement changes
- On-state test continues with little degradation in five days.
 - Previous tests show little degradation in over three weeks

CONCLUSION

- Optical pumping shows differences
 - Trap creation
 - Verification
 - Traditional luminescence techniques
 - Pulse IV for surface traps